

THE ARCHAEOLOGICAL URBAN INFORMATION SYSTEM OF VERONA: AN APPROACH TO INTEROPERABILITY THROUGH STANDARD-BASED CONCEPTUAL MODELLING

1. INTRODUCTION

In the city of Verona many very well preserved ancient monuments can still be found nowadays; some of them are currently used for exhibitions and events (e.g. the Roman theatre and the amphitheatre, widely known as the “Arena”). For this reason and for a distinctive continuity of life since pre-Roman age until today, the city has been listed since November 2000 in the UNESCO World Heritage List. Its archaeological heritage was the subject of many and important cataloguing and studying initiatives in the past years, for example the archaeological map of Lanfranco FRANZONI (1975) or other works focusing on specific time periods (ASPES *et al.* 2002 for pre- and proto-historic ages) or sectors of the city (CAVALIERI MANASSE 1993, 1998, 2003, 2008; CAVALIERI MANASSE, HUDSON 1999). All these research activities led to interesting publications that, for their own nature, contain only unstructured information that cannot be easily accessed, processed or updated.

Given the need to revise, digitalize and publish online archaeological data about the city, a pilot activity has been started in the years between 2008 and 2010 at the University of Verona with the support of some master thesis. This work produced a first GIS prototype (GROSSI *et al.* 2011), containing the collected archaeological data. Due to the success of this first experience, in 2011 a bibliographic and archive research project was started, aimed at extending the data collection to other sources and studying new methods for accessing and processing the valuable datasets that was being created; at the same time, a cooperation began at the University of Verona between the Dept. of Culture and Civilization and the Dept. of Computer Science, with the goal of implementing an IT infrastructure for archaeological data management.

As a first step, an assessment of existing and published information systems for Cultural Heritage was made. Among the international projects we considered¹:

– *Adriaticum mare*, the computerized Atlas of ancient Adriatic, developed by the International Association of the Adriaticum Mare and presided by Slobodan Čače. The project aims to create an overall map of the Ancient Adriatic and to serve as a map of major sites.

¹ For the list of all weblinks (accessed on 25/11/2014), see the Sitography at the end of the article.

- Ancient World Mapping Center resources. This research Center, of the University of North Carolina at Chapel Hill, promotes cartography, historical geography, and geographic information science as essential disciplines within the field of ancient studies.
- Archaeology Data Service. A service of York University that supports the preservation of digital data and that provides an online archive of excavations and archaeological monuments.
- Arches project. An open source system for cataloguing archaeological heritage, developed by the Getty Conservation Institute and the World Monuments Fund.
- Pleiades project. A community-built gazetteer and graph of ancient places. It publishes authoritative information about ancient places and spaces, providing services for finding, displaying, and reusing information under open license.

To the above list, other projects could be further added, all of them aimed at data collection on a large scale. For example:

- WebGIS for the heritage of Emilia Romagna region. Developed to list the artefacts in need of protection after the earthquake in 2012.
 - Sistema Informativo del Patrimonio Culturale della Regione Puglia. Developed over the past years to manage the heritage of the Puglia region.
- These projects have adopted international standards for the design and implementation of the software tools they provide, however they focus on a large-scale view of the findings or events they are dealing with and do not provide the level of detail that is required specifically for an urban context, as needed for the historical centres of Italian cities. The main active projects in this field in 2011 were the four listed below, all of them developed in Italy:
- RAPTOR, developed by the Superintendence of Archaeology of Friuli Venezia Giulia region (not accessible to the public) (FRASSINE, NAPONIELLO 2012).
 - Mappa project, created by Pisa University for the town of Pisa.
 - ArcheoFI, built by the Municipality of Florence for the town of Florence.
 - SITAR Archaeological Information System of Rome, developed by the Superintendence for Archaeology, fine arts and landscape of Rome, for the town of Rome and its metropolitan territory.

The latter proved to be the most interesting for us, both because it was based on regulations released at that time by the Ministry of Cultural Heritage, Activities and Tourism concerning the implementation of the National Territorial Archaeological Information System, namely SITAN (see: AZZENA *et al.* 2013, 2015; GOTTARELLI, SASSATELLI 2015), and because since 2010 it has been publishing some of the collected data and the underlying data model to be reused by other similar initiatives, emphasizing openness and sharing of information.

The choice of adopting this open data model led to the start of the SITAVR project (Sistema Informativo Territoriale Archeologico di Verona); in 2011 an informal cooperation was started and in 2012-2013 an official agreement was stipulated between the different stakeholders, including the University of Verona and the SITAR team. This was the basis for the kick-off of SITAVR that from SITAR inherits the data model as well as the acronym (SITA*R)².

The main objectives of the project are:

- collecting data concerning archaeological diggings, or other research activities and findings regarding the urban context of Verona;
- storing data in an IT system that allows the standardized representation of the collected information, the sharing of knowledge and the distributed access to these datasets through the web;
- using data in order to support protection of cultural assets and enhance digital cultural heritage, both to foster related scientific research and to spread this knowledge to the general audience;
- experimenting different methods to share knowledge, including advanced IT solutions that ensure interoperability between different IT systems in the field of archaeological studies. In particular, we aim at simultaneously querying different data sources (e.g. SITAVR and SITAR) so to be able, for example, to compare data from the big metropolis with data from the small colony. In general, we would like to extend interoperability with other systems, even internationally.

2. RESEARCH AIM

The SITAVR project has been implemented since 2011, with the intent to leverage the experience of SITAR for both data and application design, in order to allow interoperability between these twin systems. For both projects, the practical objective is to collect all available data about the archaeological findings and related information sources concerning Verona and Rome. The final overall goals of these projects are to support a full archaeological analysis of the data, data dissemination, and data reuse in different contexts for urban planning, safeguard, preservation, etc., in Italy and abroad. In order to reach these goals a key point is designing and developing an interoperable infrastructure.

The work presented in this paper aims at verifying the applicability of standard methodologies and advanced IT solutions in order to obtain an effective interoperability between systems that deal with archaeological data from urban contexts.

² For a detailed description of SITAVR project see: BASSO *et al.* 2015, 2016, 2017; BELUSSI, MIGLIORINI 2014; BELUSSI *et al.* 2015; SITAVR web-site: <https://sitavr.scienze.univr.it/public/>; for a detailed description of SITAR project see: SERLORENZI 2011, 2015; SERLORENZI, JOVINE 2013; SITAR web-site: <http://www.archeositarproject.it/>.

3. MATERIALS AND METHODS

The experiment has been implemented by proceeding on two parallel tracks: on one hand, working on the IT solution, adopting programming languages, formats and services adhering to the standards already used by the Italian public administrations and in European projects; on the other hand, developing a common conceptual model, sharing and consolidating concepts, definitions, descriptions and vocabularies.

Since its inception our project has put an emphasis on interoperability and data sharing, by adopting open source tools and standard methodologies for supporting the various activities. In particular, a formal modelling language (including software tools for supporting the modelling activity) was chosen in order to:

- model and describe concepts in a formal and unambiguous way (domain model) so to be able to reproduce the underlying data model in similar contexts (effective reuse);
- create a formal specification of the data model that does not rely on a specific technology, but that can easily be implemented on existing platforms (feasibility).

The choice was made for GeoUML (BELUSSI *et al.* 2006a, 2006b, 2009), an extension of UML, since it matches the above requirements, as described in the subsections 3.1, 3.2, and 3.3. In general, adhering to international standards has been a necessary requirement for the implementation of the system.

3.1 *Modelling language and tools*

UML has been adopted as formal language for the specification of the SITAVR data model at conceptual level (i.e. independently from any specific technology); in particular, the constructs allowing to define UML class diagrams have been used. The adoption of the UML approach for describing data is frequent in many international standards (e.g. ISO standards, like ISO TC 211 Geographic Information/Geomatics); however, as far as we know, no current archaeological information system devoted to the urban context has investigated the formal specification of the data with the aim not only to support implementation, but mainly to enable interoperability. Some works have adopted the UML paradigm in other archaeological and cultural heritage contexts, with different purposes (MASSUSSI *et al.* 2010; ZOGHLAMI *et al.* 2012; PFEIFFER *et al.* 2013).

GeoUML extends UML with geometric representation of the spatial properties of the data (BELUSSI *et al.* 2006a, 2006b) as defined in the ISO TC 211 standards (in particular, ISO 19107 and ISO 19109). More specifically, the GeoUML Catalogue tool has been adopted for the following reasons:

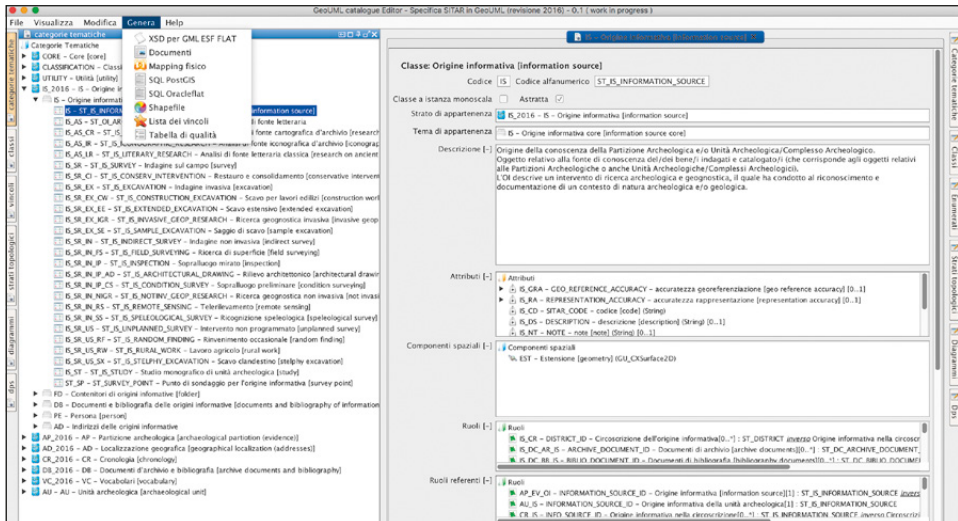


Fig. 1 – GeoUML tools: the schema in the GeoUML catalogue.

- it has been used for the specification of the Italian National Core (National topographic database) and has been adopted in other GIS-based projects by many Italian Regions;
- this approach has been studied, developed and extended since 2004 at the Dept. of Computer Science in Verona.

The GeoUML Catalogue manages the conceptual schema and at the same time it can automatically generate the mapping towards different technologies, producing the corresponding physical schemas (SQL for PostgreSQL or Oracle, XML schema, ShapeFile, etc.). In Fig. 1 the interface of the tool is shown. Note that in the left window a subset of the classes, belonging to the schema, is shown and in the central window the description of a specific class is presented. The interface allows the user to navigate through the attributes and association roles; moreover, as shown by the above highlighted menu, the automatic generation of different physical schemas is available.

3.2 Format for data exchange and mapping to international standards

In order to allow interoperability between systems (SITAVR and SITAR, and other systems as well), a common format for data exchange has been defined. The specification for this format can be generated automatically by the adopted tool (GeoUMLCatalogue) in the form of an XML syntax definition (XSD file, see Fig. 2), and allows online access to data through a web service.

```

<complexType name="Origine_informativa_information_sourceType">
  <complexContent>
    <extension base="gml:AbstractFeatureType">
      <sequence>
        <element name="UID" minOccurs="1" maxOccurs="1">
          <simpleType>
            <restriction base="string">
              <maxLength value="70"/>
            </restriction>
          </simpleType>
        </element>
        <element name="Estensione_geometry" type="gml:MultiSurfacePropertyType" minOccurs="0" maxOccurs="1"/>
        <element name="accuratezza_gisreferenziazione_geo_reference_accuracy" type="sita:0_gisreferenziazione_gisreferenziazione_gisreferenziazione_accuracy_EnumerationType" minOccurs="0" maxOccurs="1"/>
        <element name="accuratezza_rappresentazione_representation_accuracy" type="sita:0_Accuratezza_rappresentazione_representation_accuracy_EnumerationType" minOccurs="0" maxOccurs="1"/>
        <element name="codice_code" minOccurs="1" maxOccurs="1">
          <simpleType>
            <restriction base="string">
              <maxLength value="48"/>
            </restriction>
          </simpleType>
        </element>
        <element name="costo_comlessivo_lavori_total_cost" type="double" minOccurs="0" maxOccurs="1"/>
        <element name="costo_ricerche_geo_archeologiche_survey_cost" type="double" minOccurs="0" maxOccurs="1"/>
        <element name="data_cinizio_start_date_data_date" minOccurs="0" maxOccurs="1"/>
        <element name="data_cinizio_start_date_granularita_temporale_temporal_granularity" type="sita:0_Granularita_temporale_temporal_granularity_EnumerationType" minOccurs="0" maxOccurs="1"/>
        <element name="data_di_fine_end_date_data_date" minOccurs="0" maxOccurs="1"/>
        <element name="data_di_fine_end_date_granularita_temporale_temporal_granularity" type="sita:0_Granularita_temporale_temporal_granularity_EnumerationType" minOccurs="0" maxOccurs="1"/>
        <element name="descrizione_descrition" minOccurs="0" maxOccurs="1">
          <simpleType>
            <restriction base="string">
              <maxLength value="2000"/>
            </restriction>
          </simpleType>
        </element>
        <element name="Metodologia_di_acquisizione_acquisition_methodology" type="sita:0_Metodo_di_acquisizione_acquisition_methodology_EnumerationType" minOccurs="0" maxOccurs="unbounded"/>
        <element name="nome_name" minOccurs="0" maxOccurs="1">
          <simpleType>
            <restriction base="string">
              <maxLength value="250"/>
            </restriction>
          </simpleType>
        </element>
        <element name="note_note" minOccurs="0" maxOccurs="1">
          <simpleType>
            <restriction base="string">
              <maxLength value="1000"/>
            </restriction>
          </simpleType>
        </element>
        <element name="pubblicato_is_published" type="boolean" minOccurs="1" maxOccurs="1"/>
      </sequence>
    </extension>
  </complexContent>
</complexType>
<element type="sita:Origine_informativa_information_sourceType" name="Origine_informativa_information_source" substitutionGroup="gml:Feature"/>

```

Fig. 2 – An example of XML syntax produced by the GeoUML Catalogue (XSD file).

Concerning national and international standards for data modelling that we considered for the mapping of the data schema, we mention here:

- CIDOC Conceptual Reference Model and its specification CRMarchaeo (FELICETTI *et al.* 2016; DOERR *et al.* 2018; CIDOC CRM);
- AAT (Art & Architecture Thesaurus, Getty research Institute), through Simple Knowledge Organization System (SKOS).

Currently we are also analyzing the D2.8.I.9, INSPIRE Data Specification on Protected sites, Annex 1, described on INSPIRE regulation (EU Parliament and EU Council, 2007/2/CE, March 14th, 2007), in particular for mapping the class Law Constraints Decrees of SITAR.

3.3 Web services

In order to set up web services for data publishing, we have tested the standard Web Feature Service of OGC Consortium. The WFS provides access to data with a high level of abstraction, indeed it provides a set of functionalities that allow the user to specify complex queries on data, also referring to their spatial properties, and to exploit the structure of the information that was defined in the conceptual schema and was inherited in the exchange format (XML syntax). The result is an XML document, whose structure is adherent to the conceptual schema, containing also the explicit representation

of links to other connected information available through the same service or elsewhere in the Internet.

4. IMPLEMENTATION

The creation of the technological infrastructure described in section 3 allows exchanging data on the IT site; however, this would not be possible without an underlying conceptual schema, that formally describes a shared semantics for the data. This was indeed the most challenging part of the project; namely, the definition of a shared vocabulary and a set of both broad and fine-tuned concepts that can represent a bridge between the terminology used in the two projects SITAVR and SITAR.

4.1 *Requirements*

The basis for this conceptual schema was the SITAR data model, which is based on the following main concepts:

- Information Source (Origine Informativa – OI);
- Archaeological Partition (Partizione Archeologica – PA);
- Archaeological Unit (Unità Archeologica – UA).

OI can describe the activities leading to the knowledge about a specific archaeological context. Therefore, one OI can describe an excavation, a field survey, a bibliographic research, etc. Through a set of related concepts, details are provided such as the type of research being performed, the place where and time when it occurred, related documentation, geo-spatial data regarding its exact location, etc.

PA describes a piece of archaeological knowledge limited in time and space. Therefore, a PA represents a «segment of matter, a physical material in a relative stability of form (substance) within a specific space-time volume» (see the complete description in DOERR *et al.* 2018, 38-39). A PA can then be a structure, in a more or less complete form, a movable element, a stratigraphy or a geological substrate, which are important in a historical perspective. Through a set of related concepts, details are provided such as place and time of the finding, its dating and measurements, related documents such as pictures, maps, etc.

UA describes a monument or a complex aggregate of findings having a common existence and refers to a specific place and time. While the PA is the “raw” data, obtained from a mere objective observation of the available materials, the UA constitutes an aggregation and interpretation of these materials. For example, a UA can represent the Arena in Verona as it was in the Roman age. Through a set of related concepts, details are provided such as dating, related documentation and reconstruction of the monument.

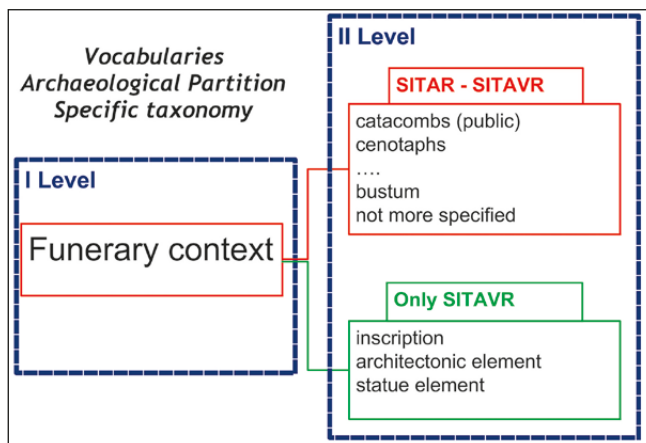


Fig. 3 – An example of the hierarchical approach used for the integration of different vocabularies. Two non intersecting sets of lemmas in a vocabulary can be linked together by finding common lemmas at a higher level in the hierarchy.

Once those three concepts and their properties were established, we moved into creating a shared vocabulary, so that SITAR and SITAVR could use the same definitions. For example, in order to describe the methodologies used in acquiring an OI, a shared set of terms has been defined so that, for example, an archaeological trench or an archaeological sample excavation has been classified as an OI of type “trench or sample excavation” in both systems.

For PA, the typology has been defined with a two-level approach, using an “objective definition” to qualitatively describe the element (e.g. structure, epigraphic element, geological substrate, etc.) and a “specific definition” to further identify the element with more precision (villa, tomb, etc.). The implementation of the latter across the two systems has proved particularly challenging; for example, new specific definitions have been introduced in SITAVR data model in order to represent those findings that could not be specifically described through more abstract concepts of the vocabulary (e.g. movable and reused elements, such as inscriptions or architectural elements). To properly extend the model, in order to address this issue, a hierarchical definition of the vocabulary has been created, where the movable elements became sub-classes of corresponding monuments and contexts. For example, a burial has been classified in both systems as a PA of type “funerary context” > “tomb”. A funerary inscription, catalogued in the SITAVR model, would have been classified as “funerary context” > “inscription”. In this way, sepulchral inscriptions, tombs, *ustrina*, etc. all belong to funerary contexts (Fig. 3).

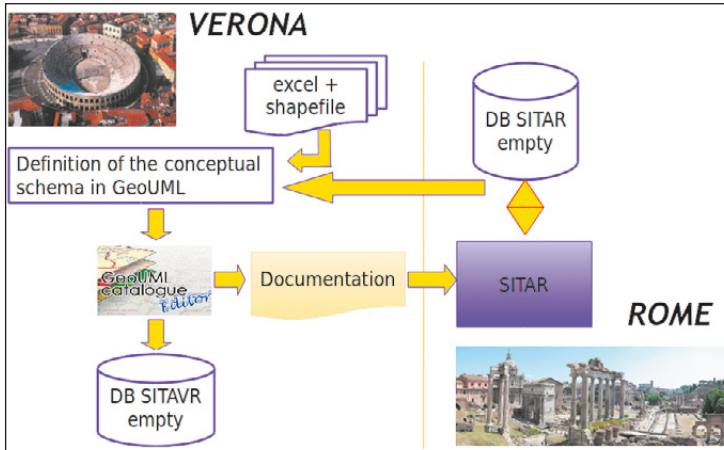


Fig. 4 – The starting phase of SITAVR project.

4.2 Development

Once concepts and vocabularies to be shared and methodologies and IT solutions to be used have been identified (section 3.1) we proceeded with specifying the conceptual schema by the GeoUMLCatalogue tool and to map concepts and vocabularies on CIDOC CRM standard and AAT. In practice, the process for data modelling started from the schema of the SITAR database (physical schema) as shown in Fig. 4.

4.2.1 Concepts modelling in GeoUML

Starting from the identified concepts (e.g. Information Source, Archaeological Partition, Archaeological Unit), the archaeological data were modelled, inside the GeoUML Catalogue, by using the formal constructs of UML such as: classes, attributes, enumerations, associations and class hierarchies (in Fig. 5 a portion of the class diagram of SITAVR is shown). A “class” (e.g. “Archaeological Partition”) represents a concept that can be “instantiated” becoming part of the database content; a class instance is a sample of the concept (that is, an instance of the Archaeological Partition, e.g. a finding representing a part of the wall of the Arena in Verona). Instances of classes are also called “objects”.

A class has “attributes” that define the class properties, while in an object the attributes contain values defining the instance (for example, the “Archive” class might have an attribute called “Name” while an instance of an “Archive” will have its “Name” set to the actual name for the archive being represented). Rules can be defined concerning the admissible values of a given attribute, in

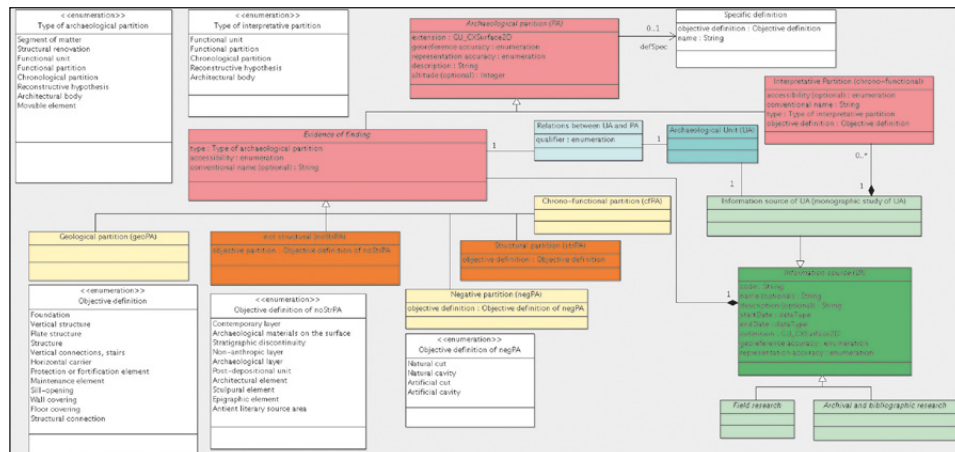


Fig. 5 – A part of SITAVR conceptual schema, described by using UML as formal language.

particular “enumerations” can be used to restrict them to a listed set of values (e.g. the “Dating method” attribute might take its values from an enumeration containing values like: materials_analysis, epigraphic_data, etc.).

“Classes” in the data model encapsulate all the relevant information about the corresponding concepts in the domain and object attributes are filled with proper values when an instance is created. On the other side, relationships between concepts are represented by “association roles” (e.g. an Information Source, i.e. an excavation, survey, etc. should have an address, which can be represented by an “address” association role between the “Information Source” and the “Address” classes); when instantiated, association roles represent links between objects (for example a link between an object representing an Information Source and the object that holds its address).

Finally, classes exist in hierarchies where the classes at the bottom (so called sub-classes) represent specializations of classes at the top of the hierarchy; usually sub-classes are created by adding new attributes/association roles; for example, the Evidence of Finding class is a specialization of Archaeological Partition class. This means that it inherits all the attributes/roles of the parent class (for example the extension attribute) and additional specific attributes for example the accessibility attribute (see Fig. 5). For more details about the technical aspects of the modelling see BELUSSI, MIGLIORINI 2017; MIGLIORINI *et al.* 2017.

4.2.2 Mapping on CIDOC CRM

In cooperation with the FP7 2013-2017 ARIADNE European project, the conceptual schema of SITAR-SITAVR has been mapped towards the

ST_ARCHAEO_PART_SPECIFIC_DEFINITION				
name_it	name_en	skos_relation	getty_name	getty_url
tra paramenti murari	filling in between walls	broadMatch	walls	http://vocab.getty.edu/aat/300002469
tra paramenti murari	filling in between walls	relatedMatch	fill (leveling material)	http://vocab.getty.edu/aat/300015132
muri di rinforzo	reinforcing wall	closeMatch	retaining walls	http://vocab.getty.edu/aat/300005073
canalizzazione	artificial channel	broadMatch	artificial water channels	http://vocab.getty.edu/aat/300133792
cippo di confine agrario	cippus (field boundary mark)	closeMatch	cippi	http://vocab.getty.edu/aat/300006963
cippo di confine agrario	cippus (field boundary mark)	broadMatch	boundary stones	http://vocab.getty.edu/aat/300006962
canali di irrigazione fosso di drenaggio	irrigation canal – drainage moat	broadMatch	distributaries (streams)	http://vocab.getty.edu/aat/300387055
canali di irrigazione fosso di drenaggio	irrigation canal – drainage moat	broadMatch	water distribution structures	http://vocab.getty.edu/aat/300006164
cippo confinario	cippus (boundary mark)	closeMatch	cippi	http://vocab.getty.edu/aat/300006963
cippo confinario	cippus (boundary mark)	broadMatch	boundary stones	http://vocab.getty.edu/aat/300006962

Fig. 6 – An example of the mapping of the SITAVR vocabularies towards the AAT.

CIDOC CRM framework and some of its extensions such as CRMarchaeo and CRMsci, and also towards the AAT through the SKOS approach. The availability of a formal specification of the data content, in the form of an UML-based conceptual schema, has been of great help in performing the semantic mapping. In summary, the three main concepts of the schema, i.e. Information Source, Archaeological Partition and Archaeological Unit have been mapped on different classes of the ontology-based model of CIDOC CRM.

In particular, since the Information Source is a very general class of objects, its instances have to be classified by the acquisition methodology that characterizes them. Therefore, we distinguished between: (i) the sources, which describe a physical process of data collection and (ii) the research studies, which analyse documents and other literary sources, obtaining two subclasses: Physical Information Source and Research Information Source. Starting from this distinction, the mapping towards CIDOC CRMarchaeo has produced different results according to the attribute “acquisition_methodology”: (i) in the first case the mapping transforms an Information Source into an instance of the class A1_Excavation_Process_Unit; (ii) in the second case the transformation produces an instance of the class E13_Attribute_Assignment, and (iii) for all the cases in which some kind of physical survey on the territory has been carried out, but it was not an excavation, the chosen class was S4_Observation.

A similar approach has been applied for the Archaeological Partitions, so the mapping involves the following classes of CIDOC CRMarchaeo: S22_Segment_of_Matter, E92_Spacetime_Volume, E22_Man_Made_Object and E25_Man_Made_Feature. Finally, the instances of the Archaeological Unit class have been mapped to instances of the class E24_Physical_Man_Made_Thing. Further details about the complete mapping of SITAR-SITAVR model towards CIDOC CRM-Archaeo will be published in an upcoming paper focused on this topic.

4.2.3 Mapping the vocabularies on Art and Archaeology Thesaurus of Getty Research Institute

During the mapping towards CIDOC CRM, the vocabularies, already shared between SITAR and SITAVR, were mapped onto the AAT vocabulary, through the SKOS approach, due to its employment within the ARIADNE project framework. In Fig. 6 we show an example of the vocabularies and their corresponding translations in English and the mapping towards the AAT.

Each vocabulary is mapped into an instance of the class E55-Type. The corresponding tag encapsulates the label containing the Italian value and the relation L54 is same-as towards a SKOS Concept with a preferred label in English and some matches with AAT terms. Notice that many different matches can be defined towards AAT terms, each one with a particular kind of match relation. Besides to the *relatedMatch* and *broadMatch* reported in the example, other possible relations are: *exactMatch*, *narrowMatch* and *closeMatch*³.

5. RESULTS

Some results have been reached in terms of interoperability, data access and standard compliance up to 2016:

- definition of a conceptual schema for SITAVR, via GeoUML tools (see SITAVR web site: <https://sitavr.scienze.univr.it/public/>);
- metadata compilation of the datasets according to the ISO Standard 19115;
- semantic mapping between the SITAVR data model and the CIDOC-CRM;
- identification of a format for data exchange (XSD) and of data interchange methods;
- implementation of a WFS service for data access and reuse;
- implementation of a WebGIS prototype for displaying and querying the collected data via web.

As a first result, thanks to a multi-user access, online availability allowed to populate the database, fostering a fast collection of data, their storage and preservation. Moreover, WFS protocol made this information content readily available by both direct queries and interoperability with other GIS systems. Last but not least, the most effective result was that the system enables archaeologists to perform queries and analysis over the integrated data collected in SITAR and in SITAVR such as:

³ See mapping properties in SKOS Reference (<https://www.w3.org/TR/skos-reference/#mapping>).

- filtering and creating datasets based on attribute values (e.g. dating, type, definition, etc.);
- transparently integrate queries over data pertaining to different areas and cultural environments.

As a concrete example, let us consider how we can evaluate the precision in geo-positioning excavations over different areas, in this case Rome and Verona, in a period between years 1900 and 2000. Without this platform, data should have been collected from different databases, then an analysis should have been performed in order to discover how the information about geo-positioning accuracy is represented in each database, then a common set of terms (vocabulary) would have been defined to allow a comparison, data would have been merged from the different sources, and finally checked for exact or partial match. Instead, all of this can be performed with a single, simple query over the developed platform.

An application of the described methodology concerns the study of how the Romans influenced local populations of Northern Italy in the process known as “Latinization”. This process started in this area from the 3rd century BC and reached its peak during the 1st century BC when, in application of the *Lex Pompeia de Transpadanis* in 89 BC, pre-existing centres, such as Verona, became in all respect colonies, and when in 49 BC, with the *Lex Roscia*, such centres obtained full citizenship and became *municipia*. This phenomenon is well known and studied, and it is indeed trivial to compare the urban structure of the town of Verona with that of Rome. Still, many secondary aspects can be studied and confirmed by comparing archaeological data from the two towns: a process that so far was done only manually and on paper.

Thanks to the many comparisons that can be drawn on the collected data (e.g. between building techniques, building materials, road networks, etc.), we can state how Latinization influenced all cultural aspects. An example can be cited as regards funeral rites. In Verona, as in Rome, the funeral area was located outside the town, along the main roads and similarly happened in all the rural context of Verona. As in Rome, burials changed according to the social status and the historical period. There are burials inside stone coffins, inside structures made by bricks and, in the rural context, even a rare example of burial inside a lead coffin. Verona therefore testifies the Latinization process through not only the urban planning and administration, but also through the burial grounds and rites.

6. CONCLUSIONS

Based on methodologies and technologies described in section 3 and 4, a custom platform has been implemented consisting of an interface for accessing the DB (PostgreSQL), a WebGIS based on GeoServer to query the system on

a geographical basis, a WFS service for online access and browsing of the provided information. Interoperability allowed us to perform transparently integrated queries and analysis over data related to different cultural environments and coming from different sources.

Future developments of the research can include: (i) further study of data interchange methods (RDF, etc.); (ii) semantic mapping between the SITAVR data model and the INSPIRE Protected Site, in particular regarding the class Law Constraints Decrees of SITAR; (iii) tests of interoperability with other systems and not only between the projects SITAR and SITAVR; (iv) design and implementation of a new graphic interface for accessing and exploring the data provided by a WFS guided by data semantics. In conclusion, the conducted research, beyond the practical purpose of creating a digital geographical archive of archaeological data, can be considered an example of good practices in data modelling and interoperability in the archaeological research field, available for further reuse.

In summary, we can state that interoperability is a difficult target: it requires resources during the whole lifespan of the data collection, not only at the beginning of the project. Thus, it is necessary that this effort has some outcomes that justify the investments, for instance: data exchange between interoperable systems should be possible (feasibility on current technology); it should be easy (and useful) to integrate external data coming from other interoperable systems with the data of the local system; the information content of the exchanged data should be of high quality, i.e., the semantic and structural mapping should be precise and lossless.

Acknowledgements

This article is based on research conducted for the creation of the Archaeological Urban Information System of Verona (SITAVR project). We are grateful to our project partners, the Superintendence for Archaeology, Fine Arts and Landscape of Verona, Rovigo e Vicenza (particularly, we thank dr. Brunella Bruno and Giuliana Cavalieri Manasse), Superintendence for Archaeology, Fine Arts and Landscape of Rome and the staff of SITAR project (particularly, we thank dr. Mirella Serlorenzi and Andrea de Tommasi). Finally we would like to thank prof. Patrizia Basso of Department of Culture and Civilization for her significant support.

ALBERTO BELUSSI, SARA MIGLIORINI

Department of Computer Science
University of Verona

alberto.belussi@univr.it, sara.migliorini@univr.it

PIERGIOVANNA GROSSI

Department of Culture and Civilization
University of Verona

piergiovanna.grossi@univr.it

REFERENCES

- ASPES A., BORGHESANI G., CASTAGNA A., LONGO L., NICOLIS F., SALZANI L., SIMEONI G., ZORZIN R. 2002, *Carta archeologico-preistorica del Comune di Verona: elenco dei siti preistorici sulla base delle collezioni del Museo di Storia Naturale di Verona*, «Bollettino del Museo civico di storia naturale di Verona. Geologia, paleontologia, preistoria», 26, 47-118.
- AZZENA G., CAMPANA S., CARAFA P., GOTTARELLI A. 2013, *Il Sistema Informativo Territoriale Archeologico Nazionale - SITAN*, in SERLORENZI, JOVINE 2013, 41-45.
- AZZENA G., BUSONERA R., NURRA F., PETRUZZI E. 2015, *From the Archaeological Map of Italy to the National Geographical Archaeological Information System. The Sardinian experience*, «Archeologia e Calcolatori», 26, 115-129.
- BASSO P., BELUSSI A., BRUNO B., GROSSI P., MIGLIORINI S. 2015, *Progetto SITAVR. Una carta archeologica per Verona*, in SERLORENZI, LEONI 2015, 155-167 (http://soi.cnr.it/archcalc/indice/Suppl_7/18_Bruno_et_al.pdf; last accessed: 25/11/2017).
- BASSO P., BELUSSI A., BRUNO B., GROSSI P., MIGLIORINI S. 2016, *Il work in progress del SITAVR: primi passi metodologici, modello dati e documenti condivisi del sistema informativo territoriale archeologico*, in F. STANCO, G. GALLO (eds.), *Atti dell'VIII Workshop Free, Libre and Open Source e Open Formats nei processi di ricerca archeologica (Catania 2013)*, Oxford, Archaeopress, 141-149 (<http://www.archaeopress.com/public/download.asp?id=%7B14C6CFBD-3371-4DF0-8971-D4ABC24E661E%7D>; last accessed: 25/11/2017).
- BASSO P., BELUSSI A., BRUNO B., GROSSI P., MIGLIORINI S. 2017, *Da Roma a Verona alle zone dell'agro: andata e ritorno. Una sperimentazione di interoperabilità tra SITAR, SITAVR e SITAIS*, in M. SERLORENZI, I. JOVINE (eds.), *Pensare in rete, pensare la rete per la ricerca, la tutela e la valorizzazione del patrimonio archeologico*, *Atti del IV Convegno di Studi SITAR (Roma 2015)*, «Archeologia e Calcolatori», Suppl. 9, 157-170 (http://soi.cnr.it/archcalc/indice/Suppl_9/15_Basso_et_al.pdf; last accessed: 25/11/2017).
- BELUSSI A., MIGLIORINI S. 2014, *A framework for managing temporal dimensions in archaeological data*, in *Proceedings of 21st International Symposium on Temporal Representation and Reasoning (TIME 2014) (Verona 2014)*, IEEE COMPUTER SOC., Los Alamitos, CA (USA), 81-90.
- BELUSSI A., MIGLIORINI S. 2017, *A spatio-temporal framework for managing archeological data*, «Annals of Mathematics and Artificial Intelligence», 80, 3-4, 175-218.
- BELUSSI A., MIGLIORINI S., GROSSI P. 2015, *Managing time dimension in the archaeological urban information system of the historical heritage of Rome and Verona*, in F. GILIGNY, F. DJINDJAN, L. COSTA, P. MOSCATI, S. ROBERT (eds.), *CAA2014. Computer Applications and Quantitative Methods in Archaeology, Proceedings of the 42th Conference (Paris 2014)*, Oxford, Archaeopress, 235-244 (<http://www.archaeopress.com/Public/download.asp?id={5CACE285-4C48-41AE-809E-E98B65C9E4CD>; last accessed: 25/11/2017).
- BELUSSI A., MIGLIORINI S., NEGRI M., PELAGATTI G. 2009, *From the conceptual design of spatial constraints to their implementation in real systems*, in *Proceedings of 17th ACM SIGSPATIAL International Conference on Advances in GIS (Seattle 2009)*, New York, ACM, 448-451 (<http://dx.doi.org/10.1145/1653771.1653841>).
- BELUSSI A., NEGRI M., PELAGATTI G. 2006a, *An ISO TC 211 conformant approach to model spatial integrity constraints in the conceptual design of geographical databases*, in *Advances in Conceptual Modeling - Theory and Practice: ER 2006 (CoMoGIS Workshops)*, Berlin, Springer, 100-109 (http://dx.doi.org/10.1007/11908883_13).
- BELUSSI A., NEGRI M., PELAGATTI G. 2006b, *Modelling spatial whole-part relationships using an ISO-TC211 conformant approach*, «Information and Software Technology», 48, 1095-1103.
- CAVALIERI MANASSE G. 1993, *Le mura di Verona*, in *Mura delle città romane in Lombardia. Atti del convegno (Como 1990)*, Como, Associazione archeologica comense, 179-215.

- CAVALIERI MANASSE G. 1998, *La via Postumia a Verona, una strada urbana e suburbana*, in G. SENA CHIESA, E.A. ARSLAN (eds.), *Optima via. Atti del Convegno Internazionale di Studi. Postumia. Storia e archeologia di una grande strada romana alle radici dell'Europa (Cremona 1996)*, Cremona, Associazione promozione iniziative culturali, 111-143.
- CAVALIERI MANASSE G. 2003, *Verona. Una polis megale cisalpina*, in *Veneto. II, Luoghi e tradizioni d'Italia*, Roma, Editalia, 21-44.
- CAVALIERI MANASSE G. (ed.) 2008, *L'area del Capitolium di Verona. Ricerche storiche ed archeologiche*, Verona, Soprintendenza per i Beni Archeologici del Veneto.
- CAVALIERI MANASSE G., HUDSON P. 1999, *Nuovi dati sulle fortificazioni di Verona (III-XI secolo)*, in G.P. BROGIOLO (ed.), *Le fortificazioni del Garda e i sistemi di difesa dell'Italia settentrionale tra tardo antico e alto medioevo. Atti del Convegno archeologico del Garda (Gardone Riviera, Brescia 1998)*, Mantova, S.A.P., 71-91.
- DOERR M., FELICETTI A., HERMON S., HIEBEL G., KRITSOTAKI A., MASUR A., MAY K., RONZINO P., SCHMIDLE W., THEODORIDOU M., TSIAFAKI D., CHRISTAKI E. et al. 2018, *Definition of the CRMarchaeo. An Extension of CIDOC CRM to support the archaeological excavation process*, Version 1.4.4, January 2018 (http://www.cidoc-crm.org/crmarchaeo/sites/default/files/CRMarchaeo_v1.4.4.pdf; last accessed: 07/06/2018).
- FELICETTI A., MASUR A., KRITSOTAKI A., HIEBEL G., MAY K., THEODORIDOU M., DOERRAND M., RONZINO P., HERMON S., SCHMIDLE W. 2016, *Definition of the CRMarchaeo. An Extension of CIDOC CRM to Support Archaeological Excavation Process*, 2016 (<http://www.cidoc-crm.org/crmarchaeo/ModelVersion/version-1.4.1>; last accessed: 25/11/2017).
- FRANZONI L. 1975, *Edizione archeologica della Carta d'Italia al 100.000. Foglio 49. Verona*, Firenze, Istituto Geografico Militare.
- FRASSINE M., NAPONIELLO G. 2012, *RAPTOR: archeologia e tutela. Verso la Pubblica Amministrazione digitale*, «Archeologia e Calcolatori», 23, 81-99 (http://www.archcalc.cnr.it/indice/PDF23/05_Frassine_Naponiello.pdf; last accessed: 25/11/2017).
- GOTTARELLI A., SASSATELLI G. 2015, *Strategia progetto e sviluppo tecnologico del portale NADIR-network di ricerca*, in SERLORENZI, LEONI 2015, 179-185.
- GROSSI P., GOTTARDI T., ZENTILINI E., ZANETTI C., GRAZIOLI V. 2011, *Proposta per una carta archeologica di Verona: un prototipo con software libero realizzato tramite alcune tesi di laurea*, in G. DE FELICE, M.G. SIBILANO (eds.), *Atti del V Workshop Open Source, Free Software e Open Format nei processi di ricerca archeologica (Foggia 2010)*, Bari, Edipuglia, 47-54.
- MASSUSSI M., MASSUSSI P., PIATTI R., TUCCI S. 2010, *Intelligent models and ideal cities: A data model for a sustainable urban planning and cultural heritage safeguard*, in F. NICCOLUCCI, S. HERMON (eds.), *Beyond the Artifact. Digital Interpretation of the Past. Proceedings of CAA2004 (Prato 2004)*, Budapest, Archaeolingua, 224-227.
- MIGLIORINI S., GROSSI P., BELUSSI A. 2017, *An interoperable spatio-temporal model for archaeological data based on ISO Standard 19100*, «ACM Journal on Computing and Cultural Heritage», Vol. 11, n. 1-5, 2017, 1-28 (<http://doi.acm.org/10.1145/3057929>).
- PFEIFFER M., CARRÉ C., DELFOSSE V., HALLOT P., BILLEN R. 2013, *Virtual Leodium: From an historical 3D city scale model to an archaeological information system*, in ISPRS. *Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. II-5/W1 2013, XXIV International CIPA Symposium (Strasbourg 2013), Strasbourg, Grussenmeyer P., 241-246.
- SERLORENZI M. (ed.) 2011, *SITAR: Sistema Informativo Territoriale Archeologico di Roma. Atti del Convegno (Roma 2010)*, Roma, Iuno.
- SERLORENZI M., JOVINE I. (eds.) 2013, *SITAR: Sistema Informativo Territoriale Archeologico di Roma. Potenziale archeologico, pianificazione territoriale e rappresentazione pubblica dei dati. Atti del II Convegno (Roma 2011)*, Roma, Iuno.

- SERLORENZI M., LEONI G. (eds.) 2015, *Il SITAR nella Rete della Ricerca Italiana. Verso la conoscenza archeologica condivisa. Atti del III Convegno (Roma 2013)*, «Archeologia e Calcolatori», Suppl. 7.
- ZOGLAMI A., DE RUNZ C., AKDAG H., PARGNY D. 2012, *Through a fuzzy spatio-temporal information system for handling excavation data*, in J. GENSEL, D. JOSSELIN, D. VANDENBROUCKE (eds.), *Bridging the Geographic Information Sciences. International AGILE 2012 Conference (Avignon 2012)*, Berlin, Springer, 179-186.

SITOGRAPHY

- AAT, Art & Architecture Thesaurus, Getty research Institute: <http://www.getty.edu/research/tools/vocabularies/aat/>.
- Adriaticum mare*: <http://adriaticummare.org/>.
- Ancient World Mapping Center resources: <http://awmc.unc.edu/>.
- Archaeology data service: <http://archaeologydataservice.ac.uk/>.
- ArcheoFI, Sistema informativo della città di Firenze: http://archeologia.comune.fi.it/PROGETTO_list.php.
- Arches project: <http://archesproject.org/>.
- ARIADNE FP7 2013-2017 project: <http://www.ariadne-infrastructure.eu/>.
- CIDOC CRM, Conceptual Reference Model: <http://www.cidoc-crm.org/>.
- GeoUML methodology: <http://spatialdbgroup.polimi.it/>.
- INSPIRE Directive (2007/2/CE-14/03/2007). European Commission 2007 (published on “Gazzetta ufficiale dell’Unione europea” on April 25th, 2007): <http://inspire.jrc.ec.europa.eu/>.
- Mappa project, Sistema informativo archeologico della città di Pisa: <http://www.mappaproject.org/>.
- Open Geospatial Consortium (OGC): <http://www.opengeospatial.org/ogc>.
- Pleiades project: <https://pleiades.stoa.org/>.
- Simple Knowledge Organization System (SKOS): <https://www.w3.org/2004/02/skos/>.
- Sistema Informativo del Patrimonio Culturale della Regione Puglia: <http://sirpac.regione.puglia.it/web/guest/ricerca>.
- SITAR – Sistema Informativo Territoriale Archeologico di Roma: <http://www.archeositarproject.it/>.
- SITAVR – Sistema Informativo Territoriale Archeologico di Verona: <https://sitavr.scienze.univr.it/public/>.
- UML, Unified Modeling Language: <http://www.uml.org/>.
- WebGIS del patrimonio culturale dell’Emilia Romagna: <http://www.patrimonioculturale-er.it/webgis/>.
- WFS, Web Feature Service: <http://www.opengeospatial.org/standards/wfs>.
- WebGIS for the heritage of Emilia Romagna region: <http://www.patrimonioculturale-er.it/webgis/>.

ABSTRACT

Since 2011 the Archaeological Geographical Information System of Verona, SITAVR, has been implemented based on the existing and well-consolidated Archaeological Information System of Rome, SITAR, developed since 2008. The main objective of the two projects is collecting information about the archaeological findings regarding the two Italian urban centres with the aim to support a complete archaeological analysis and allow for easy data reuse. The purpose of this research is twofold: (i) archaeological studies, aimed to collect data and contents, and (ii) information systems applied to cultural heritage, aimed to organize, use and preserve the data on the basis of the innovations related to methodologies, technologies and standards. In this regard, the first step in SITAVR project was to create a domain model of archaeological

data, by applying standard methodology for producing an abstract conceptual schema. Next steps were the definition of web services and a common format for data exchange; further in this direction was the creation of a mapping between this model and other international standards. The definition of the conceptual schema and the metadata, the common format for data exchange and the mapping on international standards have supported and encouraged the cooperation between SITAVR and SITAR projects. Moreover also some practical tests of interoperability between the two systems have been performed, thus demonstrating the effectiveness of the proposed approach. In particular, an experiment regarding the integrated execution of some queries on the two systems (funerary contexts and the road network of the two towns) was successfully implemented. In conclusion, our work further demonstrates that interoperability requires an initial large investment of resources, but allows to achieve results in terms of data analysis that by means of non-integrated systems cannot be easily accomplished.